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AN INTRODUCTION TO ERGONOMICS

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AN INTRODUCTION TO ERGONOMICS

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I INTRODUCTION

1. In prehistoric times men made their weapons and tools for themselves. Efficiency, and the fitting of the tool to the operator, were vital. If a man made a bad weapon and could not use it well enough, then there was soon one less designer of bad tools alive. The tradition of the craftsman making his own tools, or selecting carefully before buying until he finds those which "feel right" (that is, which fit him well), has lasted through the ages and still applies to hand tools. But few operators can try out, and throw aside if not suitable, the bigger machines of today - such as lathes, cranes or power presses - until they find one which fits them! Still less is this possible with the more complex machines of tomorrow, such as computers, automation units and supersonic airliners.

2. Therefore in our factories and homes, in the air and on the roads, we are using machines designed by others with little advice from us about how they should be made to fit our own peculiarities. This does not mean that the machines will necessarily be badly designed or that we shall not be able to use them. But it may mean that we cannot use them as well as the designer could himself, because what fits him may not fit us.

3. In the newly developing nations this problem is accentuated by the fact that the designer may well have belonged to a totally different industrial culture on the other side of the world. Moreover, design engineers are mostly, and quite rightly, concerned to improve the mechanical and electrical performance of their machine, and it is sometimes forgotten that what matters most is how well the machine works in conjunction with the operator who has to use it day after day in his routine work.

4. Now, there is nothing especially novel about emphasizing this need for a good fit between man and machine; but the difference with Ergonomics is that it emphasizes and provides the methods for a systematic scientific approach to the problem. Engineers, managers and administrators have to make the final decisions on the design, acceptance and establishment of equipment and plant, and these decisions obviously affect greatly the efficiency and welfare of the humans to be involved. Errors can be costly in both human and economic terms, but not all such errors are necessary, let alone inevitable. Research has already yielded much relevant knowledge; but in many situations the engineer or manager may still have to fall back on "rule of thumb" or guesswork. To replace such a potentially costly basis for decisions by a systematic scientific approach is a prime aim of Ergonomics. Moreover, the engineer or manager himself often can and should use the relevant research findings, provided he is competent and able to interpret them correctly; it is not essential, even though often helpful, to have the consultant advice of an Ergonomics specialist in order to adopt this scientific approach to the human factors aspect of modern technology.

What then is Ergonomics?

5. Ergonomics is defined as the study of the relation between man and the environment in which he works, particularly the application of anatomical, physiological and psychological knowledge to the problems arising therefrom. This definition, and the field of work, clearly can embrace both research and practical application, but the

precise boundaries and the various branches of the subject are by no means yet established. The four general texts so far published are by Chapanis et al. (1949), Woodson (1954), McCormick (1957) and Chapanis (1959).

6. Research is essential to increase and refine the knowledge available on the multitude of ways in which men behave, are similar to and different from engineering components, and respond to and are influenced by their task and environment. Much of what may reasonably be regarded as Ergonomics Research is still, inevitably, in the separate disciplines. But the inter-disciplinary approach is growing, despite obvious difficulties, in keeping with the fact that the anatomic, physiological, psychological, etc., reactions of a man to any given situation will be unitary, interdependent and largely inseparable components of his total behaviour pattern.

7. The essence of Ergonomics, especially as far as the present paper is concerned, is the application of this knowledge and scientific method to practical problems. In the design of equipment and environment, Ergonomics (or Human Engineering or Human Factors, broadly equivalent names used in the U.S.A.) places major emphasis upon efficiency in the operation of the equipment as measured by the speed and accuracy of the human performances. Allied with efficiency are the safety and comfort of the operator. Because the aim here is to optimize the man-machine and man-environment combinations by suitable modifying the machine and the environment, this aspect has also been termed "fitting the work to the man". Equally important, although often regarded as a separate subject from Ergonomics, are the personnel factors such as selection, training, and adaptation to environmental and working conditions. These are studied both as part of Ergonomics and as separate topics under the headings of Work Physiology and Occupational Psychology, and from this knowledge people can be helped to modify themselves, within limits, to improve the man-machine partnership; this personnel aspect has also been termed "fitting the man to the work".

How did Ergonomics develop and where is it practised?

8. What is now called Ergonomics had its beginning, on the academic side, in the requests to university scientists to study human problems in governmental ordnance factories and elsewhere during World War I. On the engineering and industrial side, the pioneer work of Taylor and Gilbreth in the field of motion and time study helped to draw attention to the value of the analysis of jobs by skilled technicians. World War II led to much greater emphasis not merely on matching men to machines by selection and training, but also, much more than previously, on the designing of equipment so that its operation was within the capacities of most normal people. This "fitting the work to the man" increased considerably the collaboration of engineers in certain fields with the biological scientists. This collaboration, beginning primarily with military problems, because it is there particularly that operators are pushed to their limits, continued after the war and led to the formation in England in 1949 of the Ergonomics Research Society. Attention has since returned to the industrial field, and the joint approach has increasingly shown its value as an ally, according to circumstances, of design engineering, work-study, industrial medicine and personnel management.

9. The field has already grown so far that it is impossible to count, for certain, the exact total of groups at work. In Great Britain there are some 15 academic research groups*, and at least four Services' sponsored units for military problems; also four private industrial companies have sections specifically devoted to ergonomics work, the largest group now being eight years old with a permanent staff of four. In Europe*, the development is similar but on the whole more scattered and a little less advanced. In the U.S.A., particularly under the impetus of military funds, development has been much more rapid. At least 130 industrial companies have organized human factors programmes with an average group staff of 10 (Kraft, 1961) and the services' sponsored units and the academic research groups are similarly more numerous. It is difficult to learn what may be happening in the U.S.S.R., but from a literature survey Ronco and

* See the Register of Research in the Human Sciences applied to Problems of Work and Directory of Relevant Research Institutions, prepared for various European countries by the European Productivity Agency of the O.E.E.C.

Sawyer (1962) conclude that "although only a few articles were found that have to do with the direct application of knowledge of man's psycho-physiological capacities to the design of machines, ... sufficient volume of pertinent material is being generated to merit systematic attention by human engineers".

Why is Ergonomics needed?

10. This question would not be asked if the subject of Ergonomics were not mainly human. Just because we are all human, we tend to think that we automatically know most of what needs to be known about man when matching up a working situation to him. But in fact the amount of specialist knowledge now available about man, even in ergonomic aspects, is such that there is probably no one man, even a specialist himself, who can learn it and know it all.

11. If a problem arises which is primarily in, say, chemistry or quality control, we quickly acknowledge if it is outside the limits of our own general knowledge and call upon the chemist or quality control specialist for his assistance. But if we have a problem to deal with involving humans, we still tend to use our own subjective opinion or go to consult the subjective opinions of other men instead of summoning a specialist, perhaps because the existence of specialists is not yet widely known.

12. Accidents, errors, poor quality and low output are the usual symptoms of a problem which amongst other things may need ergonomic attention. When a man-machine mis-match in industry today results in such symptoms, the cost of not finding a cure is often considerable but may not be so high as to compel action. But as man in the future is progressively used less for his muscle power and more and more for his ability to process information and make decisions, so he is in control of more assets and more output, and the cost of the mis-match grows in proportion. As with military problems in the past particularly, so now with modern industrial equipment the demand upon the operator grows as the complexity increases. The more the operator is stressed the greater the need to ensure a good match between man and machine to minimise the risk of error and maximise accuracy and output. This is the fundamental reason why the specialist's knowledge from Ergonomics is needed as a supplement to modern technology.

II RESEARCH

13. The wide range of Ergonomics research relevant to practical problems is best shown by references to examples drawn from the main biological sciences from which knowledge is applied. There is only space to mention a small fraction of the huge field.

14. Functional anatomy is concerned with the body framework, posture, and the use of muscles; it can, therefore, provide knowledge of the best ways in which force can be applied or objects lifted and also about the limits of joint movement. This knowledge is, of course, very important in the design of controls such as levers and foot pedals. For example, the activity of muscles during typewriting has been studied by Lundervold (1958), the strength of a man's lifting action by Whitney (1958), and a typical case-study of a practical situation (railway engine driving) in which the limb position and force required, amongst other things, were a serious impediment has been reported by Schwab (1958).

15. Anthropometry yields data on body sizes and dimensions, both for male and female, and thus can help with the optimum design of the height and size of working surfaces, the position of hand and foot controls, the shape and height of seating, and so on. For example, the usual height of a chair is 18 inches, which has been shown by Floyd and Roberts (1958) to be too high for about 70% of the male population and 60% of the female population (if wearing $1\frac{3}{4}$ inch heels). This same research by Floyd and Roberts (1958) has been the basis of a British Standard (BS 3079) which is at last bringing better dimensions to office desks and chairs in Great Britain.

16. Work physiology covers the whole field of bodily activity, particularly with reference to many different types of environment. For instance, reasonable measurements for physical work can be made in terms of calorie consumption, and on the practical side, from this knowledge, it is possible to calculate the most efficient organisation of work and rest pauses, to minimise fatigue, etc. Lehmann (1958) has shown how "hidden" rest pauses may often have to be taken and how it is more efficient to organize official pauses realistically. Again, from India, Caplan (1946) has reported an experimental study of the effects of heat on workers in the Kolar gold mines, where he estimated that with a wet-bulb temperature of above 83°F. the efficiency in a normal shift of six hours would decline by about 60%; this loss, once realised, could of course be decreased if more ventilation and air conditioning could be installed.

17. Psychology covers the whole field of human behaviour, and particularly such aspects as how an operator receives and processes "information". From this one can estimate, for instance, the rate at which the operator can be given information by a system and act upon it, what delays and errors may result, and how best to design the input and output equipment leading to and from him. Conrad (1960), in describing some of his research related to post office telephonic and letter-sorting problems, illustrates well this part of applied psychology. Among practical design researches, Gibbs' (1952) machine tool indicator should be noted, together with another proof of his method by Gordon and Radhakrishnan (1959). Again, the problems of training difficult skills are particularly relevant to newly developing countries; some recent research by Bowen and Kelley (1962) has shown how there may be a generalisable skill involved in controlling such vehicles as aircraft and ships and has resulted in a technique and equipment for training this type of skill which is greatly superior to existing methods.

18. It should also be emphasized how workers in Ergonomics are aware of the future problems likely to arise from advances in technology. As long ago as 1955, Mackworth (1955) discussed the relevance of research then for the problems to be expected when automation came, and with automation still hardly arrived Welford (1960) could survey the aspects of Ergonomics likely to bear on the design of automatic equipment and the human problems likely to arise from automation.

III APPLICATION

The approach of Ergonomics to practical problems

19. The primary emphasis is upon a scientific approach, i.e. upon objective study and the gathering of reliable facts from which deduction and recommendations can be made and proved statistically to have an adequate measure of validity. Opinionative advice and solution are avoided unless specifically requested in preference to no advice at all, and only then with great emphasis upon the unproven and speculative nature of such recommendations.

20. In tackling specific problems to fulfil the general aim to produce well-integrated man-machine combinations, the ergonomic approach has six definite sections, some or all of which are implemented according to the type and complexity of task, machine or system being considered. The first three sections are relevant when the design, redesign, or at least some modification to the design of the equipment is being undertaken. The last three are relevant when some choice or modification of personnel is desirable and can be implemented. In describing and illustrating with references these sections, there is again only space enough to mention a minute proportion of the whole field.

Design of Equipment

21. The first process, more significant with major systems than with individual machines, is to describe and analyse the system as a complete unit, using operational and physical flow diagrams as appropriate, and to subdivide the whole into funtionally separate sub-tasks. Each sub-task is then considered in turn, to decide whether the use of a man or machine as the sub-unit is more appropriate; such factors as cost, weight, size, reliability, safety and efficiency must be assessed and compared for each sub-unit separately. At the same time, the selection and training problems, as conditioned by the likely availability of suitable personnel to train and be trained, must be taken into account also as factors vitally affecting the decision between man and machine for sub-task units. Finally an optimum balance must be decided on all these factors for the combination of sub-units into the complete system. The methods of system design and the application of human factors have been described and illustrated in detail by Van Cott and Altman (1956), and broadly covering the whole field of systems engineering by Flagel (1960). Christensen (1962) has described the evolution of the systems approach and has given a commentary on the growth of Ergonomics thus far which gives a good perspective to the whole, and Kidd (1962) has debated some of the problems of methodology.

22. Second, for each machine or for each part of a system where the human element is used, the interaction between the man and the equipment must be optimised. To do this, an approach is used which is slightly different from that of the engineers, who rightly must start his thinking from the machine and concentrate upon that. The ergonomic approach is to examine the task and the operational sequence that the man will have to do and to consider the man's abilities and limitations and how they will influence the total task performance. With the man as our centre, we then work outwards from him, thus coming to examine his interaction firstly with the machine or task, and next with the immediate workspace around him (the chairs, desks, machine console, etc.) and finally with the general environment in which he and the machine are to work (thus coming to such problems as heating, lighting, ventilation, etc.). To ensure an adequate study and reliable recommendations it is important to examine in detail each one of these three zones of interaction in turn (see Table). Only in this way can we be sure to take account of all possible influences upon the man and his work. This zonal approach is implicit in much of the ergonomics literature. An explicit description of its use during the design of the operator's console for a large digital computer has been given by Shackel (1962).

23. Third, even if re-designing an existing working situation, and especially if involved in the design of a completely new machine system, the proposed and agreed final design should be evaluated by mock-ups and trials to test the validity of decisions on human factor aspects, in exactly the same way that models and trials are used to check important engineering sections of any system. Such evaluation trials should particularly use samples of the expected final operators. A general purpose, computer programmed, research tool for such evaluation work during the system design stage has been reported by Johnson et al. (1961). Gruber et.al. (1961) have described in detail the methodology of a very thorough evaluation study and thus provide a useful model for this third part of the practical ergonomic approach, which completes the design procedure and should confirm finally the equipment design established.

Personnel factors

24. Fourth, assuming choice is possible, proper personnel selection procedures should be established. As with equipment design, the selection procedure should be based on a comprehensive analysis (cf. Rodger and Cavanagh, 1959), from which a job description is prepared in precise operational terms along with an outline of the qualifications and experience required and any difficulties and distastes peculiar to the work. Decisions can then be made, which should later be validated, on the conduct of interviews and on the choice of test and questionnaire material. This basic selection procedure applies

whether we are involved with establishing the manning policy and selecting the staff for a new system being installed or, as more commonly occurs, with the broader aspects of selecting the staff at various levels in a company or industry. Thorndike (1949) discusses these techniques, and practical applications are described by Vernon and Parry (1949) and Rodger (1945). Some interesting and well validated work has been done on the selection of engineering apprentices by Frisby et al. (1959) and by McMahon (1962) and his colleagues. On the difficult problem of selecting for sensorimotor skill aptitude, Bowen and Kelley (1962) appear to have developed a promising instrumental approach, which may prove particularly relevant to the problems of newly developing nations.

25. Fifth, if special knowledge or skill is required, suitable training must be established. The job requirements and methods must be studied carefully to elicit the significant cues and features upon which correct performance will depend, so that maximum attention is given to them. Also appropriate methods must be devised for providing knowledge of results as quickly as possible during training. A general discussion of the problems and suggestions on methodology have been given, for instance, by Blain (1956) and Seymour (1959), and a review of some recent studies has been published by D.S.I.R. (1960). Also, a new approach to certain types of problem has been developed by Belbin (1957, 1958) and shown to be an advance over other methods. The subject of training cannot be left without brief mention of the advent of teaching machines (cf. Lumsdaine and Glaser, 1960, Morrill, 1961, and Ryan et al., 1962), which will undoubtedly in time help to revolutionize methods and solve some of the major teaching problems, especially of the new nations. Reasonably satisfactory validations have been reported, for instance with naval subjects by Wallis (1962), but much work is still needed before unequivocal acceptance will be possible.

26. Sixth, under the heading of personnel, attention may also be devoted to a range of problems such as welfare, labour relations, acclimatisation to heat and cold (e.g. Edholm, 1954, Burton and Edholm, 1955, Pepler, 1958), absenteeism and other reactions to shift work (e.g. Shepherd and Walker, 1957), accidents and safety (e.g. Shaw, 1954, Laner and Sell, 1960). These must not be overlooked, and are all aspects studied by Ergonomics in conjunction, where appropriate, with specialists in sociology, work study, industrial hygiene, etc.

Conclusion

27. The importance of this six-pronged approach lies in three aspects. First, it ensures comprehensive gathering of all relevant data concerning the particular problem situation, and greatly minimises the risk of wasted time and inadequate solution by premature concentration on the apparent but not real cause of a problem. Secondly, this approach emphasises that working situations are dynamic, and that any attempt to solve problems in such situations must, to be successful, study the total man-machine functioning as a series of actions and interactions, as a cine film and not as a drawing or still picture. Finally, it emphasizes that man is a whole creature and reacts as a whole to his working environment. He must therefore be studied as a whole entity from all the above different viewpoints, more or less simultaneously, if a correct perspective is to result. This emphasis and co-ordination of a global approach is one of the especial contributions of Ergonomics.

IV CONCLUSIONS

Where is Ergonomics relevant in modern industry?

28. On the shop floor there are many situations where scientifically proven methods of selecting and training operators would yield worth-while economic improvement. Organisationally it would seem that these situations can best be dealt with by personnel

and work study departments making use of technical data and consultant advice from Ergonomics where relevant. In many companies it may not be good economics to employ a full-time Ergonomics specialist for this work alone.

29. When new machines and task situations are being designed or considered for installation, Ergonomics becomes more particularly relevant, and the cost of obtaining such knowledge, particularly if it is sought early enough in the design stage, becomes relatively insignificant in proportion to the typical capital cost involved and the potential savings to be expected.

30. The same arguments apply with much greater force still as complexity increases and the design of larger production units and systems is considered. A continuous-flow production line is a typical example of a modern industrial situation requiring some thorough system design. The bigger such a line is the greater is the importance of adequate feed-back and feed-forward of information from one stage to another to maintain everything within limits; but very frequently one finds that still only the most primitive means of communication are available between operators, who are now usually at much greater distances from each other. Only thorough and extensive study of what information each operator needs from the machine and each other, and of the way that the system should be designed to present this information most simply and easily, can safeguard against lengthy commissioning time and the risk of costly shut-downs. The emphasis of the ergonomic approach on dynamic rather than static investigation and planning could be very fruitful here.

What would be correct management policy?

31. Only broad generalisations are possible, because so much depends upon the nature of a company's product and organisation. The manufacturers of complex capital goods are more likely to find ergonomic help of practical and economic value than are manufacturers of simple products. On the other hand, any manufacturer contemplating major capital expenditure on new plant or new production facilities, particularly envisaging a major increase in the complexity of his manufacturing processes, might well save much trouble later by getting ergonomic assistance early enough.

32. In general, the best criterion is probably the financial size of the company compounded with the amount of man-machine conjoint working-time involved, either (a) in the consumer's use of the product or (b) on the production floor, according to which aspect of ergonomics application is being considered. For instance, (a) on the question of Ergonomics applied to the design of the company's products, manufacturers of machine tools, motor cars, furniture and household appliances have much greater need for ergonomics knowledge than manufacturers of electrical generators, tyres, submarine cables and water tanks. Again, (b) on the question of Ergonomics applied to production methods, manufacturers with a high ratio of labour to other costs, (such as in the boot and shoe industry) with special environmental problems (such as in steel or tyre making) or with important safety considerations (such as passenger transport services) can expect significant improvements in efficiency and safety by applying ergonomics knowledge.

33. Given a 'prima facie' field of application, the scale of ergonomic activity required and the manner of obtaining it will then depend on the size and turnover of the company. In general, it would seem that only large companies, say of more than one or two thousand employees, or those with a large turnover, say of more than one or two million pounds, are likely to feel justified in employing a full time specialist on their staff. Most managements would be better served by seeking consultant advice when appropriate. This, however, points to the need for one important action. When a decision has been taken to seek ergonomic advice only when required, it is essential to establish, within the normal organisation of the company, a clear definition of who is responsible for watching over the general running of the company to detect when and where ergonomic assistance would be economically desirable. Some one or more persons should

be given the necessary training and charged with the responsibility of watching for operationally significant ergonomic problems and, when they arise, with the duty of seeking the specialist advice required. In various industries and companies this function is carried out sometimes by the medical officer, sometimes by the work study department, sometimes by the production manager, and sometimes by the chief engineer or his staff.

34. Therefore, in relation to Ergonomics, a management decision is required, in a company of any size, upon the following three points:

(a) What areasof our factory and/or products might benefit from the application of ergonomic knowledge?

(b) Does our requirement justify a full time specialist or a consultant on retainer or a consultant called in as necessary?

(c) If a consultant is to be used at any time, what department or person shall be charged with the duty of watching for significant ergonomic problems and calling in a consultant in good time?

Why and how is Ergonomics relevant to newly developing countries?

35. With its emphasis on and methods for helping towards

(a) better designed equipment, to improve ease of use and minimise operator errors, and

(b) better selection and training, to improve the skill and care of any given operator with his equipment,

Ergonomics can contribute significantly towards efficiency, safety and productivity in the newly developing countries. Less risk of error and therefore less damage and less down-time are proportionally of greater value there than in, say, the U.K. or U.S.A. because capital equipment is relatively scarcer and more valuable. Thus Ergonomics can contribute towards getting the maximum effective return per unit time from invested capital.

36. To achieve this, Ergonomics would aim at equipment designed or modified to fit properly the natives of the country, at selection and training procedures (adapted to the prevailing conditions there) to inculcate adequate skill and knowledge, and at instruction books and other aids especially designed for the particular country (not just copies or translations of the original which have usually been designed for the sophisticated technicians of the manufacturers' country). Above all, when equipment is to be purchased from abroad, Ergonomics would insist on a contract condition that the equipment must be proved to meet its full specification when in the hands of a representative group of trained but otherwise ordinary users in their native terrain. Since this is the purpose for which the equipment is bought, the onus should be on the manufacturer to see that the purpose is fulfilled.

What policy might such countries adopt?

37. A teaching and research department might be established at a principal engineering college of the country (there are several models to follow, for instance Prof. J. Lyman, University of California at Los Angeles, or Dr. W.F. Floyd, College of Technology, Loughborough). This department would concentrate on teaching the engineers and administrators of the country the technical basis of Ergonomics in equipment design and in personnel selection and training (if no Department of Psychology is available to help). It would also be concerned with monitoring the use of these techniques in the country and with seeing that they are modified to suit prevailing conditions (to avoid slavish and inappropriate copying of methods used elsewhere).

38. Separately, although having some links with such a teaching unit, an operational evaluation department might be established in association with the technical evaluation group belonging to whatever national purchasing agency is in existence. The operational evaluation department would examine, advise on, and specify modifications to the machine design, instruction books, etc., for the whole range of capital equipment being considered for purchase from abroad.

39. Such a group should be given the power to negotiate modifications with the manufacturers, and would have suitable representation on the final selection committee. It would be expected to establish its advice on the basis of operational field trials. It might also organise a subdivision in charge of the introduction of new equipment when purchased; it would do this through one or more special training centres at which the manufacturer would teach the first group of native instructors, both for centre and field work, who would carry on thereafter. Alternatively, a separate department might be established to organise this important function.

40. It is likely that some countries will already have such training centres for introducing new equipment. In such cases the way to bring in the ergonomics aspects to the full would be to send a senior engineer who is enthusiastic to a one-year course in Ergonomics. On his return he would be able to develop the statistically controlled user trials of equipment proposed for purchase, and then report on the relative merits and negotiate modifications.

41. From his knowledge of the way in which some equipment is not well adapted to the conditions and users in its country of origin, (e.g. Shackel, 1959), the author is certain that there are many instances where a policy, such as that sketched above, would greatly improve the operational usage and minimise the waste and 'down-time' which are so often dismissed at present as operator error or ignorance. It is because man is so adaptable that the designer is often able to hide the shortcomings of his machine design behind the skill of the operator, who is rightly proud of that fact. But the more skill required and the less well-trained the operator, the more easily he may break down under stress and make an expensive error. This is not his fault, and the task of Ergonomics is to simplify the machine design enough and train the operator enough to remove the risk of error but leave the pride of skill.

42. In the achievement of this goal Ergonomics will make a very real contribution both to job satisfaction and to productivity in the newly growing nations.

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TABLE 1.

THE ZONAL APPROACH IN ERGONOMICS

I. MAN

Consideration of Sex, Age, Size, Physique, Intelligence, Experience, Training, Motivation

Definition of operational modes e.g. searching, tracking, monitoring, decision-making

required in final situation and thus consideration of abilities and limitations of human operator for all aspects of the task.

II. MAN-MACHINE INTERACTION

Influence, on operator and his decisions, of

Displays - sensory input to operator

Controls - motor output from operator

Panel Layouts; display-control compatibility

III. MAN-WORKSPACE INTERACTION

Influence of Machine size on position, posture and reach
Chairs, desks, etc.
Adjacent machines, structures and material etc.

IV. MAN-ENVIRONMENT INTERACTION

Influence of Physical aspects upon behaviour and performance
Chemical
Biological
Psychological

Physical - Light and colour, noise, heat, ventilation, gravity, movement, electromagnetic and nuclear radiation.

Chemical - Gas or liquid, composition, pressure, smell.

Biological - Microbes, insects, animals.

Psychological - Workteam, command structure, pay and welfare, shift conditions, discomfort or risk, socio-psychological aspects of the particular factory, neighbourhood, town and type of industry concerned.

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